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19 August 2020

Version of attached file:

Published Version

Peer-review status of attached file:

Peer-reviewed

Citation for published item:

Roxburgh, Heather and Hampshire, Kate and Tilley, Elizabeth A. and Oliver, David M and Quilliam, Richard S. (2020) 'Being shown samples of composted, granulated faecal sludge strongly influences acceptability of its use in peri-urban subsistence agriculture.', *Resources, conservation recycling* : X., 7 . p. 100041.

Further information on publisher's website:

<https://doi.org/10.1016/j.rcrx.2020.100041>

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Being shown samples of composted, granulated faecal sludge strongly influences acceptability of its use in peri-urban subsistence agriculture

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ARTICLE INFO

Keywords:

Human excreta derived fertiliser
Subsistence farming
Circular economy
Sanitation
Integrated nutrient management

ABSTRACT

Using human excreta derived fertiliser (HEDF) in agriculture reduces dependence on diminishing phosphorus rock reserves, improves soil health, and facilitates sustainable nutrient recycling. Such schemes have particular scope for expansion in peri-urban areas of low-income countries, where large quantities of faecal sludge from on-site sanitation systems are available. However, public acceptability is a critical unknown factor. This study used surveys of 534 peri-urban subsistence farmers in Blantyre, Malawi, to investigate the public acceptability of HEDF. Two factors are highlighted as having a particularly strong association with acceptability: showing a sample of composted, granulated faecal sludge to participants at the start of the survey, and having heard of HEDF before. For instance, almost all participants who were shown the composted, granulated sample and had prior knowledge of HEDF were willing to buy maize grown in HEDF (96%). Conversely, less than a third of participants who had not heard of HEDF before and were not shown the composted, granulated sample were willing to do so (30%). Maize was the most widely accepted crop for use with HEDF, as there is perceived to be little contact between the edible parts and the ground. This suggests that HEDF has the potential to be widely accepted by subsistence maize farmers and the general public in Malawi. However, uptake rates could be substantially improved with public engagement campaigns involving demonstrations or samples of a visually appealing product, and by promoting the concept through channels such as farmer radio programmes or agricultural extension workers.

Introduction

Using human excreta derived fertiliser (HEDF) in agriculture has a long and geographically diverse history (Ferguson, 2014). This practice occurs both formally in higher income countries, and informally in the Global South (Christodoulou and Stamatielatou, 2015; Thebo et al., 2017), and can produce crop yields comparable to those grown with commercial synthetic fertiliser (Moya et al., 2017). Despite the widespread availability of human excreta, the majority of phosphorus currently used in agriculture comes from phosphorus rock (Karamesouti and Gasparatos, 2017). However, with a growing recognition of the geopolitical risks associated with a dependence on commercial phosphorus mining, and with ‘peak phosphorus’ potentially being reached in the coming decades, there is increasing interest in harvesting the agricultural value from human excreta at greater scale (Chowdhury et al., 2017; Iwaniec et al., 2016).

One region with soil that could benefit particularly strongly from HEDF is sub-Saharan Africa. Crop yields in many parts of the continent

are constrained by soil infertility and a lack of soil moisture (Tadele, 2017), whilst financial constraints mean that many farmers are unable to use synthetic fertiliser in sufficient quantities for their needs (Danlami et al., 2016). Organic soil amendments, such as HEDF, can improve soil health by providing nutrients and increasing water retention capacity, resulting in increased productivity and resistance to dry conditions (Eden et al., 2017; Oldfield et al., 2018). Human excreta is widely available from on-site sanitation systems such as pit latrines, although currently, the majority of this excreta does not have a safe or productive destination (Nakagiri et al., 2015; Peal et al., 2020). Use of HEDF, particularly in peri-urban areas, can therefore strengthen waste management and agricultural linkages within a circular economy, and benefit resource-poor farmers (Trimmer and Guest, 2018).

Whilst there are clear benefits from using HEDF in agricultural systems, there is often concern about the public acceptance of such ventures. Humans are naturally predisposed to avoid faeces due to a psychological system that has evolved to protect us from sickness (Curtis et al., 2011), and faeces are generally endowed with deep

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<https://doi.org/10.1016/j.rcrx.2020.100041>

Received 2 April 2020; Received in revised form 25 June 2020; Accepted 13 July 2020

Available online 16 July 2020

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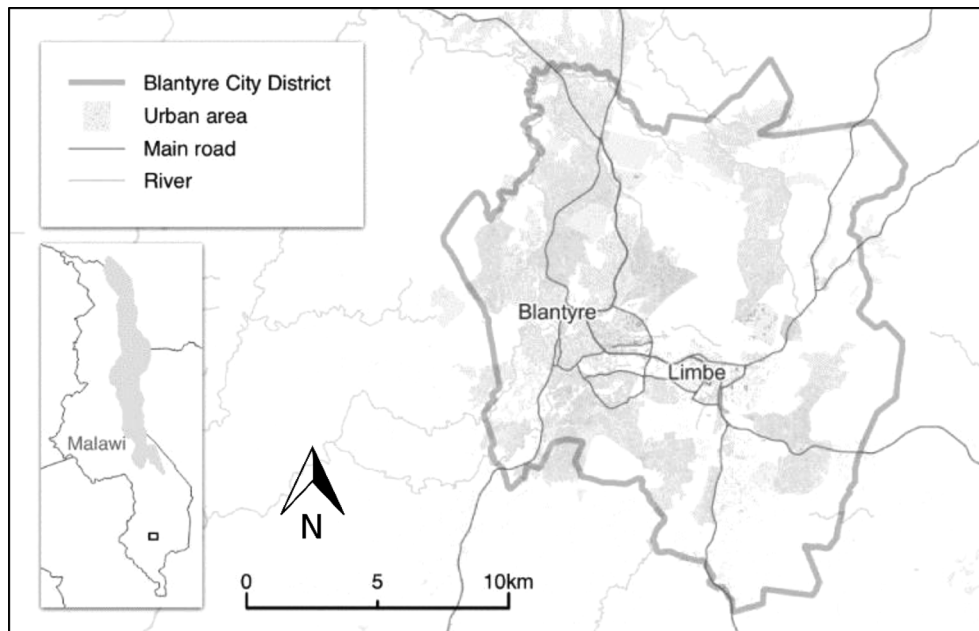


Fig. 1. Location of Blantyre and Limbe within Blantyre City District.

cultural significance as a symbol of filth and disgust (Jackson and Robins, 2018). Promoting HEDF to a disinterested or oppositional population therefore has potential to raise ethical concerns and/or be economically unfeasible. Studies trying to gauge the socio-cultural acceptability of using HEDF typically assume that certain cultures, demographics, or types of farmer may be predisposed, and attempt to identify such characteristics using surveys (e.g. Cofie et al., 2010). Alternatively, interviews, and other ethnographic techniques might be used to examine the particular features and practices of farmers who already use HEDF (e.g. Knudsen et al., 2008), or more broadly, explore what human excreta means to society in general (e.g. Van Der Geest, 1998). Acceptability of using HEDF is commonly assessed by asking hypothetical questions to farmers who do not currently use HEDF (e.g. whether they would be willing to use HEDF on their own farms), and the general public (Appiah-Effah et al., 2015).

HEDF is used in agriculture in many countries around the world, both with and without the initiation or support of external organisations such as NGOs. In some areas it is ubiquitous, e.g. 92% of surveyed farmers in Nghe An province, Central Vietnam, used HEDF (Mackie Jensen et al., 2008), whilst in other areas it is much rarer, e.g. 4% of surveyed farmers in Ashanti region, Ghana, used HEDF (Appiah-Effah et al., 2015). Some farmers are enthusiastic about the use of HEDF, whilst others are disgusted, although most have a perception somewhere between these two extremes (Buit and Jansen, 2016) and there is often embarrassment and sensitivity when discussing the use of HEDF (Knudsen et al., 2008). Certain structural barriers to using HEDF exist; for example, in India, this may be due to persisting legacies of caste (Simha et al., 2017), whilst in Islamic countries this may be linked to religious notions of purity (Khalid, 2017). However, the presence of such barriers does not necessarily determine acceptability of HEDF. Muslim farmers in Pakistan were keen to use HEDF provided that the process was economical and efficient (Khalid, 2017), whilst farmers in Ghana were not interested despite there being no obvious societal or faith-related reason (Appiah-Effah et al., 2015). Any differences in receptivity between demographic or farming groups are often marginal (Cofie et al., 2010), although an appreciation of the nutritive value of HEDF, together with the associated benefits to crop growth, is often associated with a greater acceptance (Cofie et al., 2010; Mariwah and Drangert, 2011). Previous studies have provided detailed snapshots of practices and attitudes in places where HEDF is used; however, they do

not necessarily advance an understanding of how to scale-up HEDF use in areas where it is not currently used.

The aim of this study was to assess factors influencing the public acceptability of using HEDF in peri-urban agriculture for a range of locally grown crops, using the sub-Saharan African country of Malawi as a case study. Specifically, the objectives were to: (1) define an appropriate method of measuring acceptability; (2) investigate the relationship between acceptability and other factors (such as demographic characteristics, prior knowledge of HEDF, and viewing samples of HEDF); and (3) determine which factors had the greatest influence on acceptability, in order to inform potential marketing strategies for scaling up of HEDF business ventures.

Methods

Malawi was selected for this study because it is a densely populated nation with only a small proportion of land suitable for cultivation despite being heavily dependent on subsistence farming (Harris et al., 2018). Agriculture extends onto marginal land which results in poor crop returns, whilst spatial constraints mean there is little opportunity to rotate crops or allow land to lie fallow in order to preserve soil fertility (Li et al., 2017). There is therefore an urgent need to improve the health and productivity of the soil, although the use of organic fertilisers, such as compost, is rare due to a lack of practical knowledge and raw materials, labour-intensive application, difficulty of transportation (due to bulk), and dependence on commercial fertiliser (Cai et al., 2019; Ndambi et al., 2019).

Fieldwork was conducted between December 2018 and March 2019, in the urban conglomeration of Blantyre and Limbe, which sits within the administrative boundary of Blantyre city district (Fig. 1). This location was selected due to the high density of people and the substantial amounts of human excreta being generated. The urban population continues to engage in small-scale subsistence farming, and thus provides a potential market within a localised context.

The main data collection method utilised was a questionnaire survey with members of the public. The design of this questionnaire was informed by a pilot survey and preliminary qualitative work, involving semi-structured interviews with peri-urban farmers. Data collection was carried out by three Malawian fieldworkers, all fluent in the Chichewa language, familiar with the local area, and trained in

environmental research and data collection methods. They also had personal experience of farming on their family land.

Questionnaire design

In order to capture the attitudes of members of the public towards HEDF use, it was first necessary to formulate and pilot questions that were clear and concise, and could capture feelings towards the use of HEDF in a variety of situations and degrees of intimacy. Therefore, preliminary interviews were conducted with 39 subsistence farmers. The interviews were used to identify local terms used to describe materials and processes, and to design and pilot suitable questions to capture how people felt about using HEDF. Interviews were conducted across three locations: a high-density urban settlement (Ndirande); a mid-density peri-urban settlement (Kapeni), and a low-density peri-urban settlement (Chigumula). Farmers were recruited by following a transect walk through each location and stopping at every 'nth' household (where 'n' was determined by location) to invite the household to participate. Interviews were conducted in either Chichewa or English, according to participant preference.

As a result of the interviews, the term 'human manure' was used to describe HEDF when talking to participants, as this was found to be the locally used, widely understandable, vernacular term for any kind of fertiliser or soil amendment derived from human excreta (i.e. HEDF). Examples of human manure used locally included faecal sludge, wastewater sludge, and excreta, which had received some degree of treatment (such as dehydration or composting) to reduce odour.

The following hypothetical questions were developed and tested for use in the public survey:

- Whether the participant would buy crops (maize, pumpkins, tomatoes, leafy green vegetables, and beans) grown in human manure (yes, no, maybe – each crop evaluated independently);
- Whether the participant would feel uncomfortable if a fellow passenger on a bus carried a sack of human manure (very uncomfortable, somewhat uncomfortable, comfortable, unsure);
- Whether the participant would feel uncomfortable if their neighbour used human manure on their farm (very uncomfortable, somewhat uncomfortable, comfortable, unsure); and
- How the participant would describe a farmer who used human manure on their farm (words volunteered were classified into 'positive' or 'negative' descriptions).

These questions are termed the 'attitudinal indicators' and functioned as a composite measure of acceptability in the public survey.

Piloting

Following the development and trial of the attitudinal indicators, they were formulated into a pilot questionnaire, which also captured demographic information and whether or not the participant had heard of HEDF before. The pilot questionnaire was trialled with 102 members of the public recruited at three fruit and vegetable markets around the city, administered by a male fieldworker, and took about 8 min to complete. The fieldworker began by explaining the concept of human manure as "using human excreta or faecal sludge as a fertiliser, after it had been treated to remove smell and any harmful pathogens, so that it is safe to use on crops and does not pose a risk to people". A proportion (41%) of the participants were then shown an example of HEDF in the form of dried faecal sludge, in cake-form (Fig. 2a). This material was taken from a sludge drying bed at the local wastewater treatment plant, which is a faecal sludge discharge point for registered pit emptying companies. It is routinely sold to local farmers by workers at the treatment plant. The rest of the participants were not shown any sample, and therefore relied only on the explanation given by the administrator, and any relevant prior knowledge and experience, to

conceptualise the term 'human manure'. Participants were then asked their opinions on HEDF.

After piloting, extra sections were added to the questionnaire to capture additional data on farming practices and willingness to pay for HEDF. The attitudinal indicator and demographic questions remained the same. By the time the main survey was administered, a sample of composted, granulated faecal sludge had been acquired from a local pit emptying business (Fig. 2b). This material was produced by thermophilic composting of faecal sludge to remove pathogenic organisms, and then mechanically pulverising the treated faecal sludge using a rotating sieve to produce a granular substance resembling soil. This sample was shown to all participants of the main survey as an example of HEDF as it provided a more accurate representation of what commercialised HEDF would look like (i.e. treated to remove pathogenic organisms, and processed into a form that can be easily applied to fields).

Survey

The main questionnaire survey was conducted with 432 participants, recruited across seven fruit and vegetable market sites, three of which were used for the pilot survey. The questionnaire was administered by one male and one female fieldworker. The initial explanation given to participants was the same as with the pilot survey and all participants were shown an example of HEDF, in the form of a sample of composted, granulated faecal sludge, acquired from a local supplier (Fig. 2b). The questionnaire included most of the same questions as the pilot questionnaire, but was expanded to include questions on past and anticipated farming practices. The questionnaire took about 15 min to complete.

Markets where the questionnaires were administered were purposefully chosen to represent a selection of large and small market sites across the city. Participants were recruited using time-space sampling, whereby questionnaire administrators were stationed at the entrance to market sites according to a randomised schedule, and asked every 'nth' person passing if they would participate in the survey. The 'n' value was adjusted according to the flow of people passing. The sample size for the survey is representative of the population of the Blantyre/Limbe urban conglomeration (margin of error: 5%, confidence level: 95%), which was estimated at 920,226 in 2016 by the National Statistics Office (National Statistical Office, 2017).

Data from the surveys was inputted into SPSS (IBM SPSS Statistics Version 23). Chi square tests for independence were used to test for associations between categorical data, and the Mann Whitney U test was used to test for correlations between continuous and categorical data. Statistically significant differences in demographic characteristics of respondents between the pilot and main surveys, and associations between demographic characteristics / recruitment locations and responses to the attitudinal indicator questions / prior knowledge about HEDF, were identified. Finally, associations between being shown samples of faecal sludge at the start of the survey / having heard of HEDF before, and responses to the attitudinal indicators, were assessed.

When presenting results of Chi square tests, Yates' Correction for Continuity is shown for comparisons where characteristics were defined by just two levels (e.g. male and female), in order to compensate for potential overestimation of the Chi square value when used by a 2×2 table (Hoffman, 2019). Post-hoc testing was carried out for tables greater than 2×2 by calculating *p*-values from adjusted residuals and comparing these to an α value adjusted using the Bonferroni correction, in order to compensate for potential type 1 family wide errors (Holm, 1979; García-Pérez and Núñez-Antón, 2003).

Ethical consent for the interviews and surveys was obtained from the University of Stirling General University Ethics Board (reference numbers: GUEP472 and GUEP544), and from the Malawi National Committee on Research in the Social Sciences and Humanities (reference number: NCST/RTT/2/6), prior to commencement of fieldwork.

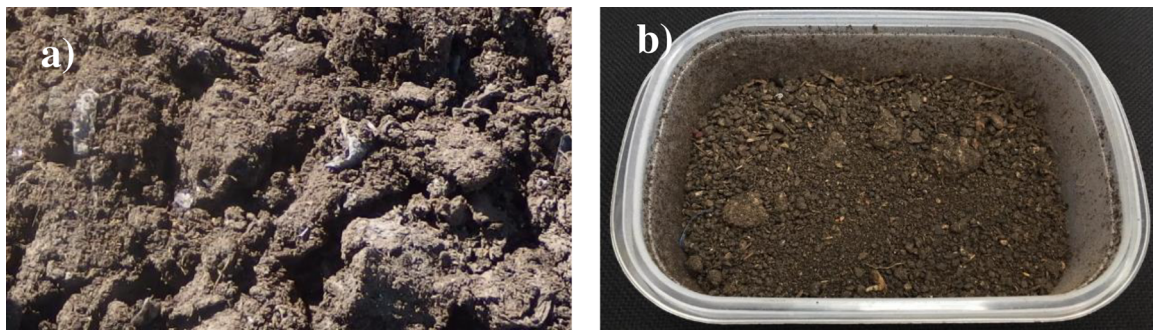


Fig. 2. Samples of a) dried faecal sludge, and b) composted, granulated faecal sludge, shown to survey participants.

Results

When data analysis commenced, striking differences in the acceptability of HEDF were found between the results of the pilot survey and the main survey. Consequently, results from the pilot and main survey are presented side by side for comparison below, in Tables 1, 4 and 5.

Participant demographics and farming characteristics

The median ages of participants were 35 and 29 for the pilot and main surveys respectively, and there was a significant tendency for participants of the main survey to be older ($p < 0.001$). Both surveys had a small majority of female participants (58%) (Table 1). Almost all participants (90% and 92% respectively for the pilot and main survey) were Christian, and the majority were from the Blantyre city district (79%, question asked in main survey only). Almost half of participants described their position within the family as 'household head' (47% and 42% respectively for the pilot survey and main survey), one third described their position as 'wife of household head' (35% and 33%), and approximately one fifth described themselves as the 'child of household head' (17% and 23%). Almost all of participants had attended primary school (99%) and more than half had attended secondary school (56% and 71%). A significantly greater proportion of participants had attained higher levels of education in the main survey, as compared to the pilot survey ($p < 0.05$). Lomwe, Ngoni, and Yao were the most commonly represented tribal groups, making up around three quarters of participants in both surveys (31% and 42% Lomwe, 24% and 18% Ngoni, and 22% and 10% Yao in the pilot and main survey, respectively). In the main survey, there was significantly more Lomwe ($p < 0.01$), whilst there were significantly more Yao in the pilot survey ($p < 0.01$). The asset ownership patterns (measured as a proxy for wealth) of participants were significantly different between the two surveys ($p < 0.01$), with a higher proportion of participants owning televisions in the main survey (71%, compared to 54% in the pilot survey). This was not a consequence of the additional market sites visited in the main survey, as the significant difference remained when comparing participants recruited at Blantyre, Limbe, and Zingwangwa market sites only.

The majority of participants from the main survey who had been engaged in farming activities at some point in the last four growing seasons ($n = 301$; 70% of total main survey participants) had small plots of land (≤ 1 hectare) (Table 2). Typically, farmed land was owned (88%), and was located close to the household plot (74%). All but three (99%) of the farmers grew maize, and the majority tended to keep and consume the maize that they grew: 80% did not sell any maize at all, and only 5% sold more than half of their crop. Two thirds of participants (66%) owned livestock of some kind. Thus, participants in the main survey who engaged in farming activities could be characterised as smallholder subsistence maize farmers. Almost half (46%) of participants had previously received a fertiliser subsidy coupon; however, only 18% had received a coupon during the last growing season.

Attitudes towards human manure

Demographic characteristics and recruitment locations of all respondents (from both the pilot and main survey) were checked for significant associations with their responses to the attitudinal indicators and prior knowledge of HEDF (Table 3). Characteristics that had significant and consistent associations with not accepting human manure use were Yao (ethnicity) or Muslim, i.e. these characteristics were significantly associated with fewer positive responses to all five attitudinal indicators ($p \leq 0.05$). Whilst some other demographic characteristics showed significant associations with some attitudinal indicators, no others showed such consistent and strong associations with all of them.

Showing the composted, granulated faecal sludge sample to the participant evoked a more positive response to the attitudinal indicator questions compared to showing either the dried faecal sludge sample, or no sample (Table 4). Significant differences for all five attitudinal indicators were found between participants seeing the composted, granulated sample and seeing the dried sample, and between people seeing the composted, granulated sample and not seeing any sample ($p < 0.001$). However, there were no significant differences in attitudinal indicator responses between participants not seeing a sample and being shown the dried sample. Participants shown the composted, granulated sample were significantly more likely to respond positively to all the attitudinal indicator questions ($p < 0.001$), which suggests that seeing the composted, granulated sample had a significant and positive effect on the participants' acceptance of HEDF, whilst seeing no sample, or the dried sample, did not.

Having previously heard of HEDF also had a significant effect on participants' responses to the attitudinal indicators (Table 5). Significant differences ($p < 0.05$) were found between all attitudinal indicators, and effect sizes were strongest amongst participants who were not shown the sample of composted, granulated faecal sludge. This result suggests that prior knowledge of HEDF has a significant and positive association with a participant's acceptance of HEDF, and the association is stronger in the absence of seeing the composted excreta sample.

Perceived suitability of different crops

Another important factor in public opinion emerged from both the preliminary interviews and the questionnaires, which was the varying degrees of perceived acceptability of different crops for being grown in HEDF. For instance, participants generally agreed that maize was acceptable for growing in HEDF: 52% and 93% of participants from the pilot and main surveys respectively said that they would buy such maize. Leafy green vegetables were generally agreed to be less suitable for growing in HEDF than maize; 23% and 82% of participants from the pilot and main surveys respectively said that they would buy leafy green vegetables grown in this way. This is statistically significantly lower than the acceptance rates for maize ($\chi^2 = 35$, $p < .001$ for the pilot survey, and $\chi^2 = 118$, $p < .001$ for the main survey, using the

Table 1
Demographic characteristics and recruitment locations of participants.

		Pilot survey participants (n = 102)		Main survey participants (n = 432)	
Recruitment location	Blantyre	30	(29%)	95	(22%)
	Chirimba			37	(9%)
	Limbe	40	(39%)	95	(22%)
	Lunzu			34	(8%)
	Manje			32	(7%)
	Ndirande			95	(22%)
	Zingwangwa	32	(31%)	44	(10%)
Gender	Female	59	(58%)	249	(58%)
	Male	43	(42%)	182	(42%)
Area of residence	Blantyre city district	Question not asked		344	(79%)
	Blantyre rural district			53	(12%)
	Thyolo district			16	(4%)
	Chiradzulu district			2	(1%)
	Elsewhere			17	(4%)
Relationship to household head	Household head	48	(47%)	180	(42%)
	Wife of...	36	(35%)	144	(33%)
	Child of...	17	(17%)	100	(23%)
	Other	1 ^a	(1%)	8	(2%)
Highest educational level attended	No education	2 ^a	(2%)	9	(2%)
	Primary	43*	(42%)	119	(27%)
	Secondary	44*	(43%)	239	(55%)
	Vocational/higher	12	(12%)	64	(15%)
Ethnicity	Chewa	8	(8%)	45	(10%)
	Lomwe	32**	(31%)	183	(42%)
	Yao	22**	(22%)	41	(10%)
	Ngoni	24	(24%)	78	(18%)
	Tumbuka	8 ^a	(8%)	16	(4%)
	Nyanja	0 ^a	(0%)	13	(3%)
	Sena	2 ^a	(2%)	40	(9%)
	Tonga	1 ^a	(1%)	4	(1%)
	Ngonde	0 ^a	(0%)	2	(1%)
Religion	Other	5 ^a	(5%)	9	(2%)
	Christian	92	(90%)	399	(92%)
	Muslim	10	(10%)	32	(7%)
Asset ownership	Other	0 ^a	(0%)	1	(< 1%)
	No assets	4	(4%)	12	(3%)
	Mobile	42**	(41%)	111	(26%)
	Mobile and TV	49*	(48%)	265	(61%)
	Mobile, TV, and vehicle	7	(7%)	44	(10%)

Bold indicates the difference between the pilot and main survey is significant at alpha level corrected by sequential Bonferroni method, or Yates' Correction for Continuity (for 2 × 2 tables). * $p < 0.05$ ** $p < 0.01$ *** $p < 0.005$

^aThere were not enough observations to determine whether the difference was significant.

Chi-square goodness-of-fit test), but in the case of those who saw the composted, granulated sample, still relatively high. The difference in acceptability between the growing of maize and leafy vegetables in HEDF is less prominent for participants who had been shown the composted sample than for those who were not.

During the initial preliminary interviews, when participants could expand on their opinions in detail, farmers explained that acceptability was related to the degree of contact that the edible part of the crop was perceived to have with the ground. Maize was considered as a suitable crop for growing in HEDF because the edible part of the plant is situated on a stalk high above the ground: the contamination risk is considered

low. For leafy green vegetables, on the other hand, farmers highlighted the proximity and exposure of the edible part of the crop to the ground as a greater contamination risk:

"For maize and tomatoes [grown in human manure] people can buy and eat it, because the fruit is up a stem, but for leafy green vegetables [grown in human manure], people can't buy them." [Female, 49 years old, 0.5 Ha farm]

"Leafy green vegetables grow on the ground, so they are in contact with human manure, that's why I can't use [human manure] on leafy green vegetables." [Male, 30 years old, 1 Ha farm]

Other crops caused a divergence of opinion; some farmers thought that pumpkins could be grown in HEDF due to the edible part of the crop being protected from contamination by a thick skin. Others thought that pumpkins grew too close to the ground to be suitable:

"For the pumpkins it is okay [to use human manure] as we clean them and eat the inside part." [Female, 25 years old, 3 Ha farm]

"The pumpkins grow on the ground, in contact with human manure, so I don't want to buy and eat them." [Male, 30 years old, 1 Ha farm]

Discussion

This study has examined the public acceptability of using HEDF in peri-urban agriculture for a range of different locally grown crops in Blantyre, Malawi, and shown that the practice can be acceptable to a significant proportion of the population. Therefore, there could be a substantial market among peri-urban farmers in Blantyre for HEDF. Two factors were identified as having a particularly strong and positive influence on public opinion: firstly, being shown a sample of composted, granulated faecal sludge, and secondly, having previously heard of the idea of using HEDF.

The strongest effect on responses to the attitudinal indicator questions came from showing participants a sample of composted, granulated faecal sludge. The sight and odour of raw excreta naturally provokes disgust (Curtis et al., 2011), which is why transformation of the substance – both physically and conceptually – is important for its acceptance in agriculture (Buit and Jansen, 2016). It is therefore easier to ascertain people's opinions of using HEDF more accurately by giving them an example to view, so that they can visualise what kind of substance is being discussed and thus form their opinions accordingly. However, the visual appearance of HEDF is variable; there was a considerable difference in appearance between the dried faecal sludge taken from the wastewater treatment works by local farmers, and the commercialised composted, granulated sample. The composted, granulated sample resembled fertile soil, and the sight of this sample appeared to reassure participants about the concept of human manure, and led to significantly more positive responses. The lumpy dried faecal sludge sample however, whilst odourless, may have maintained enough resemblance to human excreta to not have the same effect, and thus there was no difference in response between those people who saw the dried faecal sludge sample and those who saw no sample at all.

Whilst the visual appearance of the composted, granulated faecal sludge sample was clearly important, it is not possible to say from this study which parts of the treatment/processing procedure, i.e. composting or pulverising, were most effective in securing public acceptance, or whether both were equally critical. Likewise, we cannot determine whether viewing the dried faecal sludge sample would have been similarly influential if it had been ground into a different texture. Exploring how visual attributes (e.g. colour, texture) and processing techniques (e.g. granulating, pelletizing) can influence people's perception of HEDF products would generate additional criteria that can be used for further quantifying the acceptability of HEDF.

In light of these findings, it becomes easier to understand why previous surveys of the public acceptability of HEDF have produced such diverse results. For instance, a study conducted in Madagascar, where samples of composted human excreta were shown to farmers, found that 72% of farmers were willing to use it on their own farms

Table 2
Characterisation of farming practices.

		Farming participants ^a (n = 301; 70% of total main survey participants)	
Farm size (Ha)	Mean	1.5	
	Range	0.0002 – 150	
	Standard deviation	9.2	
Farm ownership	Own all land	264	(88%)
	Rent all land	20	(7%)
	Own part, rent part	14	(5%)
Distance to farmland	At or near household plot	224	(74%)
	Less than one day journey	72	(24%)
	One day journey or more	6	(2%)
Maize harvest from farmer's last growing season ^b (kg)	Mean	920	
	Range	0.5 - 15,000	
	Standard deviation	1,305	
Amount of maize sold from farmer's last growing season ^b	No maize sold	242	(80%)
	Less than half	29	(10%)
	About half	7	(2%)
	More than half	14	(5%)
	All or almost all	0	(0%)
Fertiliser usage in farmer's last growing season ^b	Used synthetic fertiliser	255	(85%)
	Used plant manure ^c	10	(3%)
	Used animal manure	99	(33%)
	Used human manure	10	(3%)
	No fertiliser used	35	(12%)
Livestock ownership	Own fowl	185	(61%)
	Own sheep, goats, or pigs	67	(22%)
	Own cows	27	(9%)
	No animals	102	(34%)
Farming practices	Farmed last growing season	236	(78%)
Fertiliser subsidy coupons	Have ever received	137	(46%)
	Received last growing season	53	(18%)

^aFarming participants' refers to participants who grew food in the last four growing seasons.

^bFarmer's last growing season' refers to the last time that the participant grew food.

^cPlant manure' is the local term used to refer to compost made from plant material and food waste.

(Moya et al., 2017). However, other studies, such as those of Appiah-Effah et al. (2015) and Mariwah and Drangert (2011) in Ghana found lower acceptability rates of 32% and 46% respectively. In the latter two studies, samples of HEDF were not shown, and so participants had to rely on their own imagination to visualise the substances described as 'faecal sludge compost' and 'sanitised excreta'. Like our study, not providing a composted excreta sample resulted in lower acceptability rates by participants.

Participants who had come across the idea of using HEDF prior to the survey were also significantly more likely to respond positively to the attitudinal indicators. This result suggests that greater familiarity with the concept of HEDF results in increased likelihood of acceptance. However, unlike being shown a sample, prior knowledge of HEDF is not randomly allocated among respondents. Instead, these participants may have a background, worldview, or cultural orientation that means they are more likely to become exposed to such information, and draw positive inferences from it (Kahan et al., 2013). Further research could determine whether differential effects of information exposure occur for different sub-populations.

Even participants with a positive view of HEDF were not necessarily willing to use it on any type of crop. The perceived degree of contact between the edible part of the crop and the soil was important in discerning acceptability, and crops tended to fall on a spectrum between maize (the most acceptable) and leafy green vegetables (the least acceptable), depending on the morphology and phenology of the crop. This difference was more pronounced in the case of the pilot survey. Similar results have been found in studies of recycled water, albeit

primarily in high-income country contexts; for example, a study of the general public in Israel showed greater willingness to use recycled wastewater for purposes which were perceived to have lower human contact (Friedler and Lahav, 2006). Interestingly, participants in Blantyre had resistance to higher perceived levels of contact with the crop despite all participants being asked to evaluate HEDF on the basis that it had been suitably treated, and posed no risk to users. It may be that the reassurances on safety were not believed, or that they were not sufficiently strong to temper disgust completely.

Disgust is closely linked to perceived safety, having developed as a psychosocial disease-avoidance mechanism designed to resist contact with dangerous substances (Curtis et al., 2011). However, assurances of safety do not necessarily eliminate disgust, e.g. it is possible for disgust to be elicited from an object known to be sterile (Rozin and Fallon, 1987). Disgust is often considered a basic emotional system or sensory effect (Celeghin et al., 2017; Panksepp, 2007), and it is not always possible for people to consciously elicit reasons for their reactions of disgust. During the farmer interviews, participants were often unable to explain precisely why they felt disgusted by the idea of HEDF, or why they did not feel disgusted: they just did. As a result, interviews were not a particularly helpful tool for evaluating the reasons why people chose to accept HEDF or not. By contrast, the surveys, with controlled variables in the form of different representations of the substance, provided a more insightful picture into what strategies might be used to increase public acceptability.

Most demographic categories (e.g. gender, age, education) did not show strong, consistent relationships with the attitudinal indicators.

Table 3
Relationships of recruitment and demographic characteristics with attitudinal indicators and prior knowledge (pilot and main survey participants).

		Has heard of human manure before	Knows someone using human manure	Would buy maize grown in human manure	Comfortable with human manure being carried on a bus	Comfortable with neighbour using human manure	Describes a person using human manure positively	Would use human manure on their own farm
Gender								
	Female (n = 308)	200 (64%)	84 (27%)	259 (84%)	228 (74%)	236 (77%)	143 (46%)	228 (74%)
	Male (n = 225)	152 (68%)	62 (28%)	195 (87%)	162 (72%)	175 (78%)	121 (54%)	163 (72%)
Recruitment location								
	Blantyre (n = 126)	85 (67%)	28* (22%)	105 (83%)	85 (52%)	90 (71%)	60 (48%)	84 (66%)
	Chirimba (n = 37)	24 (65%)	5 (14%)	35 (94%)	33* (89%)	35** (95%)	22 (59%)	30 (81%)
	Limbe (n = 135)	82 (61%)	41 (30%)	106* (79%)	87* (64%)	97 (72%)	63 (47%)	93 (69%)
	Lunzu (n = 34)	28 (82%)	10 (29%)	33* (98%)	30* (88%)	30 (88%)	18* (53%)	30 (88%)
	Manje (n = 32)	25 (78%)	18*** (56%)	31* (97%)	30*** (94%)	28 (88%)	17 (53%)	29* (91%)
	Ndirande (n = 95)	65 (68%)	22 (23%)	89* (94%)	81** (85%)	81 (85%)	49 (52%)	78* (82%)
	Zingwangwa (n = 76)	43 (57%)	22 (29%)	56* (74%)	45*** (59%)	51 (67%)	36* (47%)	47** (62%)
Relationship to household head								
	Household head (n = 228)	145 (64%)	66 (29%)	194 (85%)	163 (71%)	176 (77%)	113 (50%)	156 (68%)
	Wife of... (n = 180)	115 (64%)	54 (30%)	153 (85%)	132 (73%)	139 (77%)	92 (51%)	139 (77%)
	Child of... (n = 117)	85 (73%)	24* (21%)	100 (85%)	89 (76%)	91 (78%)	54 (46%)	89 (76%)
Highest educational level								
	Primary (n = 162)	106 (65%)	49 (30%)	129** (80%)	107* (66%)	116* (71%)	75 (46%)	118 (73%)
	Secondary (n = 283)	190 (67%)	74 (26%)	251* (89%)	223* (79%)	233* (82%)	145 (51%)	219 (77%)
	Vocational/higher (n = 76)	48 (63%)	18 (24%)	66 (87%)	52 (68%)	54 (71%)	40 (53%)	47 (62%)
Ethnicity								
	Chewa (n = 53)	37 (70%)	15 (28%)	48 (91%)	45* (85%)	45 (85%)	28 (53%)	45 (85%)
	Lomwe (n = 215)	133 (62%)	66 (31%)	185 (86%)	159 (74%)	169 (79%)	104 (48%)	164* (76%)
	Yao (n = 63)	37 (59%)	21 (33%)	42*** (67%)	32*** (51%)	36*** (57%)	25** (40%)	34*** (54%)
	Ngoni (n = 102)	63 (62%)	21 (21%)	91 (89%)	75 (74%)	81 (79%)	53 (52%)	76 (75%)
Religion								
	Christian (n = 491)	325 (66%)	134 (27%)	425 (87%)	369 (75%)	388 (79%)	247 (50%)	369 (75%)
	Muslim (n = 42)	26 (62%)	11 (26%)	29*** (69%)	21*** (50%)	23*** (55%)	18** (43%)	21*** (50%)
Asset ownership								
	No assets (n = 16)	6 (38%)	5 (31%)	13* (81%)	10 ^a (63%)	11 ^a (69%)	7 ^a (44%)	10 ^a (63%)
	Mobile (n = 153)	102 (67%)	52 (34%)	121** (79%)	104 (68%)	109* (71%)	65* (42%)	108 (71%)
	Mobile and TV (n = 314)	210 (67%)	80 (25%)	277* (88%)	245* (78%)	259** (82%)	167* (53%)	243 (77%)
	Mobile, TV, vehicle (n = 51)	34 (67%)	9 (18%)	44 (86%)	32 (63%)	33* (65%)	26 (51%)	30 (59%)

Bold font indicates difference between different categories of respondent is significant at alpha level corrected by sequential Bonferroni method, or Yates' Correction for Continuity (for 2×2 tables). * $p < 0.05$ ** $p < 0.01$ *** $p < 0.005$

^aThere were not enough observations to determine whether the difference was significant.

Table 4
Relationship between attitudinal indicator responses and samples of excreta shown.

	Pilot survey		Main survey		Chi Square test (with Yates' Correction for Continuity) between...					
	Sample not shown (n = 60)	Dried faecal sludge sample shown (n = 42)	Composted, granulated faecal sludge sample shown (n = 432)		Sample not shown (n = 60) and dried sample shown (n = 42)	Sample not shown (n = 60) and composted, granulated sample shown (n = 432)		Dried sample shown (n = 42) and composted, granulated sample shown (n = 432)		
Would you buy the following crops if they were grown in human manure?										
Maize	31 (52%)	22 (52%)	402 (93%)		$\chi^2 = 0$ $p = 1.000$	$\chi^2 = 82$ $p < 0.001$		$\chi^2 = 63$ $p < 0.001$		
Pumpkins	16 (27%)	14 (33%)	376 (87%)		$\chi^2 = 0$ $p = 0.613$	$\chi^2 = 115$ $p < 0.001$		$\chi^2 = 72$ $p < 0.001$		
Tomatoes	23 (38%)	16 (38%)	362 (84%)		$\chi^2 = 0$ $p = 1.000$	$\chi^2 = 61$ $p < 0.001$		$\chi^2 = 47$ $p < 0.001$		
Leafy green vegetables	13 (22%)	10 (24%)	352 (82%)		$\chi^2 = 0$ $p = 0.989$	$\chi^2 = 95$ $p < 0.001$		$\chi^2 = 67$ $p < 0.001$		
Beans	25 (42%)	16 (38%)	370 (86%)		$\chi^2 = 0$ $p = 0.875$	$\chi^2 = 62$ $p < 0.001$		$\chi^2 = 54$ $p < 0.001$		
How would you feel if someone boarded a bus carrying a bag of human manure?										
Uncomfortable	43 (72%)	30 (71%)	67 (16%)		$\chi^2 = 0$ $p = 0.989$	$\chi^2 = 92$ $p < 0.001$		$\chi^2 = 72$ $p < 0.001$		
Comfortable	17 (28%)	11 (26%)	363 (84%)							
Don't know ^a	0 (0%)	1 (2%)	2 (1%)							
How would you feel if your neighbour used human manure on their farm?										
Uncomfortable	30 (50%)	22 (52%)	64 (15%)		$\chi^2 = 0$ $p = 0.610$	$\chi^2 = 37$ $p < 0.001$		$\chi^2 = 17$ $p < 0.001$		
Comfortable	30 (50%)	18 (43%)	364 (84%)							
Don't know ^a	0 (0%)	2 (5%)	4 (1%)							
How would you describe a person who uses human manure on their farm?										
Positively	30 (50%)	13 (31%)	222 (51%)		$\chi^2 = 1$ $p = 0.321$	$\chi^2 = 18$ $p < 0.001$		$\chi^2 = 25$ $p < 0.001$		
Negatively	27 (45%)	20 (48%)	54 (13%)							
Unclear ^a	0 (0%)	2 (5%)	36 (8%)							
No answer ^a	3 (5%)	7 (17%)	121 (28%)							

Notes

^aThere were not enough observations to determine whether the difference was significant.

However, two particular demographic groups (i.e. being Muslim and/or from the Yao ethnicity), were significantly less likely to have a positive view of HEDF. The two characteristics are interrelated, as Yao people

are largely Muslim. A strong focus on water-based cleanliness is important in Islamic culture, and this has been cited as a reason why HEDF use has not always been welcomed in Muslim communities

Table 5
Relationship between attitudinal indicators and having heard of human manure before

	Pilot survey: dried faecal sludge sample shown / sample not shown ^b (n = 102)					Main survey: composted, granulated faecal sludge sample shown (n = 432)					
	Not heard before (n = 47)		Heard before (n = 55)		Chi square test (with Yates' Correction for Continuity)	Not heard before (n = 135)		Heard before (n = 297)		Chi square test (with Yates' Correction for Continuity)	
Would you buy the following crops if they were grown in human manure?											
Maize	14	(30%)	39	(71%)	$\chi^2 = 16$ $p < 0.001$	116	(86%)	286	(96%)	$\chi^2 = 15$ $p < 0.001$	
Pumpkins	5	(11%)	25	(46%)	$\chi^2 = 13$ $p < 0.001$	105	(78%)	271	(91%)	$\chi^2 = 14$ $p < 0.001$	
Tomatoes	9	(19%)	30	(55%)	$\chi^2 = 12$ $p = 0.001$	98	(73%)	264	(89%)	$\chi^2 = 17$ $p < 0.001$	
Leafy green vegetables	3	(6%)	20	(36%)	$\chi^2 = 11$ $p = 0.001$	94	(70%)	258	(87%)	$\chi^2 = 17$ $p < 0.001$	
Beans	9	(19%)	32	(58%)	$\chi^2 = 15$ $p < 0.001$	100	(74%)	270	(91%)	$\chi^2 = 20$ $p < 0.001$	
Potatoes	Question not asked					96	(71%)	265	(89%)	$\chi^2 = 21$ $p < 0.001$	
How would you feel if someone boarded a bus carrying a bag of human manure?											
Uncomfortable	40	(85%)	33	(60%)	$\chi^2 = 8$ $p = 0.004$	32	(24%)	35	(12%)	$\chi^2 = 10$ $p = 0.001$	
Comfortable	6	(13%)	22	(40%)		102	(76%)	261	(89%)		
Don't know ^a	1	(2%)	0	(0%)		1	(1%)	1	(< 1%)		
How would you feel if your neighbour used human manure on their farm?											
Uncomfortable	35	(74%)	17	(31%)	$\chi^2 = 21$ $p < 0.001$	33	(24%)	31	(10%)	$\chi^2 = 16$ $p < 0.001$	
Comfortable	10	(21%)	38	(69%)		99	(73%)	265	(89%)		
Don't know ^a	2	(4%)	0	(0%)		3	(2%)	3	(< 1%)		
How would you describe a person who uses human manure on their farm?											
Positively	8	(17%)	35	(64%)	$\chi^2 = 22$ $p < 0.001$	52	(39%)	170	(57%)	$\chi^2 = 22$ $p < 0.001$	
Negatively	33	(70%)	14	(26%)		31	(57%)	23	(8%)		
Unclear ^a	2	(4%)	0	(0%)		10	(29%)	26	(9%)		
No answer ^a	4	(9%)	6	(11%)		42	(31%)	78	(26%)		

Notes

^aThere were not enough observations to determine whether the difference was significant.

^bIn the pilot survey, participants were either shown a sample of dried faecal sludge, or not shown any sample, before completing the survey. There was no statistically significant differences in responses to the attitudinal indicator questions found between being shown or not shown the dried sample, as shown in Table 4.

(Nawab et al., 2006). Nonetheless, the role of this should not be overstated; most (81%) Muslim participants who were shown the composted, granulated faecal sludge sample ($n = 32$) were willing to buy maize grown in HEDF, and most (73%) of those who intend to farm in the future ($n = 26$) said they would be willing to grow maize in HEDF. Therefore, even among demographic groups who are less receptive to HEDF use, high levels of acceptance are still found after showing the composted, granulated sample.

The positive response from the public towards the composted, granulated sample suggests that use of HEDF in peri-urban agriculture has potential to be widely accepted by subsistence farmers and the general public. Maize is the staple food of Malawi, and is grown more widely and in greater volume by subsistence farmers than any other crop (National Statistical Office, 2017), providing a strong potential market for HEDF in maize cultivation alone. However, uptake rates likely could be substantially improved by incorporating demonstrations with samples (in a processed form that is more visually appealing to the audience) into public engagement campaigns and by promoting the concept through channels such as farmer radio programmes or agricultural extension workers. Whilst situated within a different context, there is precedence for such an approach in places like Singapore and San Diego, where campaigns involving educational and demonstrational activities have been successfully used to facilitate public acceptance of controversial wastewater reuse technologies (Ricart and Rico, 2019; Furlong et al., 2019). Similar projects without such outreach schemes have however been decisively rejected (Morgan and Grant-Smith, 2015).

This study intended to focus solely on the aspect of public acceptability in the HEDF use debate, and therefore participants were asked to evaluate HEDF on the basis that it posed no risk to users. However, even after public acceptability is established, creation of a safe and effective market for HEDF still poses many logistical challenges that require further research. Entrepreneurs will need to make sufficient profit whilst also adhering to treatment standards, set at a level to provide public protection whilst avoiding unnecessary stringency (Strande et al., 2014). Such standards would need to be straightforward to regulate and follow, ensure sufficient removal of pathogenic micro-organisms, and control levels of other contaminants (such as heavy metals and pharmaceuticals) where necessary. Sufficient maturation of the compost must also be ensured, in order to provide appropriate levels of nutrition to the soil. Any lapse in standards could result in reputational damage to the market, as subsistence farmers are generally resource-poor and therefore unwilling to risk unreliable inputs (Moya et al., 2017). Barriers to export for crops grown in HEDF also persist, as such crops are prevented from being classed as 'organic' and fulfilling certain commonly used agricultural standards (Moya et al., 2019). Nonetheless, it appears that in the case of Blantyre, public acceptability at least does not pose a barrier.

Conclusion

Quantitative surveys of the public in Blantyre, Malawi, have revealed two factors as having a particularly strong and significant association with willingness to use HEDF in agriculture. These are: being shown a sample of composted, granulated faecal sludge at the beginning of the survey, and having prior knowledge of using HEDF. These results suggest that being able to see samples of composted, granulated faecal sludge can result in higher levels of trust and confidence in HEDF. Further research is needed to confirm which visual attributes (e.g. colour, texture) and processing techniques to achieve them (e.g. granulating, pelletizing) are most effective in influencing acceptance. Whilst the results suggest that prior knowledge of HEDF also has a positive effect, further work would also be needed to confirm whether this is causal or correlated, and whether the outcome is the same for different sub-groups within the population.

The high percentage of respondents willing to use HEDF on their

own farms demonstrates that there is a substantial market for such a product. However, the scale of success will depend on appropriate marketing strategies, with demonstration sites and the provision of free samples in a visually appealing form likely to play a key role in increasing uptake. This sensitization could be supported by a wider promotion effort through services such as the Farmer Radio station and Agricultural Extension Workers. Further research to refine a public engagement campaign and demonstration strategy, tailored for different sub-groups of the population, would be beneficial. It will also be important to establish a price point for the product, and explore how other adaptations, such as branding or certification, affect this. Successful uptake could result in substantial amounts of phosphorus being recovered from human excreta, with positive implications for soil fertility, food and nutrient security, and monetary savings for peri-urban subsistence farmers. Whilst there are many additional technical, regulatory, and economic challenges on the pathway to creating a viable, safe, market for HEDF, there appears to be strong demand for such products among subsistence farmers.

Author statement

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

This research was funded by the Natural Environment Research Council as part of the IAPETUS Doctoral Training Programme (NE/L002590/1). In-kind support was kindly provided by WASHTED, The Polytechnic - The University of Malawi. Many thanks to the research participants for generously sharing their time and experiences with us, to our dedicated and talented fieldworkers: Mr Wilson Phiri, Miss Tamandani Kaliwo, and Mr Thandizo Chitheka, and to the two anonymous reviewers, who provided helpful and constructive feedback on the manuscript.

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